ARS SPECIAL REPORT

HIGH QUALITY HAY

ARS 22-52

February 1960

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

SUMMARY

The national hay crop, which in value exceeds $2 billion a year, varies in quality more than any other great crop. Hay of good quality makes a balanced feed on which ruminants can grow normally and produce up to moderate levels. Poor hay is low in nutrients.

Research has established three general rules for improving quality of hay crops: (1) Aim for high nutrient content in the growing plants. (2) Cut early when nutrients are near peak. (3) Dry rapidly to conserve feeding value. Following are guidelines for applying these rules with present knowledge:

* Many forages can provide hay of good feeding value. Legumes are normally richer than grasses in protein and in carotene (pro-vitamin A). But grasses well managed can provide adequate nutrients for a dependable feed.

* In many areas, legume-grass mixtures are preferable choices for crop production, also for palatability of the feed.

* Whatever the forage, leafy, not stemmy, varieties are always preferable for their favorable proportions of protein, vitamins, and minerals.

* Use of varieties bred for specific advantages, such as resistance to troublesome pests, reduces production costs, gives larger yields, and improves quality and persistency of stands. Buying seed certified for true-to-variety performance is advised.

* Production of good hay crops merits the use of fertilizer, lime, water management, and pest control measures, as needed.

* Up-to-date recommendations for cutting different forages are based on evidence that early cutting yields more nutrients per acre and better feeding returns.

* Whatever harvesting methods and equipment are chosen, efficient haymaking aims at two goals: to reduce moisture to a safe storage level and to conserve all possible green color and leaves.

* Rapid drying saves feeding value of hay because the slower the drying the greater the nutrient losses, and rain can severely damage a potentially good hay. Conditioning devices that promote uniform drying of swaths are worth considering as aids to speed field drying. Applying forced air to speed the final drying stage gives consistent advantages in climate areas where rain is a hazard.

Information in this report was provided by the Agricultural Engineering Research Division, Animal Husbandry Research Division, Crops Research Division, Entomology Research Division, Farm Economics Research Division, Soil and Water Conservation Research Division of the Agricultural Research Service, and the Grain Division of the Agricultural Marketing Service

HIGH QUALITY HAY

More extensive use of research findings on hay quality would enable many dairy farmers and livestock growers to improve the efficiency of their production. The importance of quality in this crop--that is, the nutritive value and palatability for feed--is shown by facts and figures such as these:

* The United States hay crop is big business, its value exceeding $2 billion a year. In quantity, the hay crop in recent years has averaged more than 100 million tons.

* Hay as now produced varies in quality more than any other great crop in this country's agriculture. Protein and other nutrients lost after hay is cut often mount to 30 percent or more. Much of this costly loss is preventable.

* Hay of good quality is a balanced ration that can provide for growth of ruminants and production up to moderate levels.

* Poor quality hay, by contrast, is inefficient feed. It either (a) gives disappointing returns in growth and production or (b) causes excessive expense for other feeds to bring rations up to efficient levels. Poor hay, damaged by rain, can cost more to harvest than good hay. Cattle tend to eat less of poor hay.

* More than nine-tenths of the hay now produced is made by farmers and ranchers for their own stock. Quality therefore depends on their own know-how and management.

* Hay is likely to increase in use and usefulness. The trend toward grassland--forage land--farming reflects efforts of dairy farmers and livestock growers to shift more of their land from row crops to legume and grass forage. Success in such adjustments depends to a considerable extent on the quality of the forage in whatever form it is fed.

Drying forage in the sun is an ancient practice. The Romans, 2,000 years ago, arrived at remarkably clear understanding of haymaking problems. The agricultural writer Columella pointed out: "There is a measure to be observed in drying hay, that it be put together neither oven dry nor yet too green; for, in the first case, it is not a whit better than straw for it has lost its juice; and in the other, it rots in the loft if it retains too much of it, and after it is grown hot it breeds fire and sets all in a flame." He described the haymaking process as throwing the hay loosely together for a few days to "heat and concoct itself" and then to cool before farmers put it up in mows.

Through many centuries, the improvement of hay was limited to simple advances such as saving good seed for planting.

The transformation of hay from one of the most chancy of feeds into far more dependable and efficient feed has become possible only in recent decades through the teamwork of many sciences.

This report presents selected information from today's knowledge on the importance of hay quality and means of achieving it. The supporting evidence is drawn from research by the Agricultural Research Service either alone or in cooperation with State agricultural experiment stations.

Detailed recommendations for hay crop production and haymaking in specific types of agricultural operation are given in publications by the U.S. Department of Agriculture and State experiment stations and extension services.

BASIC FACTS ON QUALITY

A sound start toward improving hay quality is some understanding of what is meant by quality in this feed crop and how a good quality hay differs from a relatively poor one in appearance and in usefulness.

The accepted definition of hay quality that guides research workers, farmers, and ranchers alike may be worded in different ways but the thought is the same. Hay quality is nutritive value plus palatability; or, combining the two essentials, hay quality is feeding value.

U.S. grades for measuring hay quality by physical characteristics have been in official use since 1923. The system provides for grading 11 classes of hay at 4 quality levels--from No. 1 grade (high quality) down to No. 3 grade (relatively poor) and Sample grade (very poor). Federal specifications are set forth for each grade, mainly dealing with greenness and leaf and limitations on foreign material, such as weeds or other objectionable matter. Table 1 shows grade requirements in these respects for several classes of hay in grades 1 to 3.

TABLE 1.--U.S. Grade Requirements for All Classes of Alfalfa, Alfalfa Mixed, Timothy, and Clover Hays

Class and U.S. grade	Minimum leaves	Minimum green color	Maximum foreign matter
Alfalfa and alfalfa mixed hays:	*Percent*	*Percent*	*Percent*
No. 1	40	60	5
No. 2	25	35	10
No. 3	10	10	15
Timothy and clover hays:			
No. 1	40	40	10
No. 2	25	30	15
No. 3	10	10	20

Grades for hay were developed by the U.S. Department of Agriculture primarily to facilitate the marketing of the crop by providing uniform grades throughout the country and a common language that would be understood by the buyer and seller. In many research studies with hay, the United States hay standards are used to describe the quality of the hay. The standards are also used as a basis of quality evaluation in hay shows and extension education programs.

Measuring quality by physical characteristics--even by trained inspectors who follow official procedures--cannot achieve the precision of chemical analyses or animal feeding tests as a guide to the true feeding value of hay.

The U.S. grading system, however, can serve as a satisfactory measuring stick when more precision is impractical, as shown by various tests. Such tests confirm for the farmer the importance of leafiness and greenness--which he can see and work for--by relating these hay quality signs to hidden values in protein, carotene (pro-vitamin A) and other livestock feed essentials.

Chemical analyses show that the more valuable nutrients in hay decrease in successively lower grades. Figures in table 2 indicate such decreases in crude protein and nitrogen-free extract (a part of the carbohydrate fraction) in alfalfa hay samples. Relatively high nitrogen-free extract values usually indicate highly digestible feed.

TABLE 2.--Association of Grade and Nutrient Content in Alfalfa Hay of Three U.S. Grade Levels[1]

Hay, by U.S. grade	Samples	Crude protein	Nitrogen-free extract	Crude fiber
	Number	*Percent*	*Percent*	*Percent*
No. 1	12	22.5	45.2	22.8
No. 2	12	16.9	43.2	30.8
No. 3	15	16.8	36.8	38.3

[1]Source: Data from Agricultural Research Center studies in 1949-50 and 1952-53.

Analyses of nutrient content of leaves and stems of hay also support the observational grading system in its stress on leafiness. The leaves of alfalfa hay far surpass stems in crude protein and in carotene (table 3).

TABLE 3.--Basic Differences in Leaf and Stem Composition in Alfalfa Hay[1]

Portion of plant	Crude protein	Carotene	Crude fiber
	Percent	*Mg. per pound*	*Percent*
Leaves	25.3	35.5	17.1
Stems	11.3	5.5	44.6

[1]"Composition of Cereal Grains and Forages," National Research Council Publication 585. 1958.

Besides their importance for protein and carotene, leaves contain more of the mineral nutrients than stems, more calcium and phosphorus, for example. All vitamin values of a forage are mainly concentrated in the leaves, including B vitamins, which cattle and sheep synthesize in the rumen but which hogs and horses require as feed essentials.

Many feeding tests have shown that animals are sensitive to the differences in chemical constituents of hay and that the grading system is a practical yardstick of productivity. A higher grade of hay tends to give consistently better returns in animal growth and meat or milk production than a lower grade. Table 4 shows the effect on milk production when Holstein dairy cows at the Huntley Field Station, Huntley, Mont., were fed experimentally on high- and low-grade alfalfa hays.

TABLE 4.--Milk Production of Cows Fed High- and Low-Grade Alfalfa Hays

Hay grade	Crude protein	Crude fiber	Dry matter intake per day per cow	Milk yield per day
	Percent	*Percent*	*Pounds*	*Pounds*
U.S. No. 1.....	18.6	21.2	36.2	42.6
U.S. No. 3.....	14.6	32.4	28.2	36.7

The high importance of palatability of hay is recognized in defining hay quality as nutritive value plus palatability. A leafy green hay combines both these essentials to a favorable degree. There is ample evidence from livestock feeding tests that the U.S. hay grades indicate general levels of likely hay consumption. Large dry matter intake is essential for obtaining high production from rations predominantly forage.

GROWING QUALITY IN HAY CROPS

Choice of Species and Varieties

Many different forages can provide hay of good feeding value.

Suitable legumes and grasses average about equal in total digestible nutrients, on a pound for pound basis. Alfalfas, clovers, and other legumes have the merit of containing especially good proportions of nutrients for animal feed. That is, the legumes are normally richer than grasses in protein and also in mineral and vitamin substances, including carotene which herbivorous animals convert into vitamin A.

In many areas, legume-grass mixtures are outstandingly favorable choices. The presence of a grass lessens soil erosion and aids in lengthening the life of a hay meadow. A legume, by its nitrogen-fixing capacity, supplies nitrogen to the associated grass.

Best results with mixtures are attained when suitable kinds and proportions are established and a grass is not allowed to crowd out a

legume. Thus managed, legume-grass mixtures in many areas have given greater yield and as good or better quality than the same grass or legume alone.

Mixed hay has advantages in palatability, particularly if cattle are to be fed on hay as a sole diet at any time. Livestock are known to crave some variety. In one series of experiments, cows ate more and produced more milk when fed entirely on alfalfa-timothy hay of top quality than when fed on hay of similarly good quality made from either alfalfa or timothy alone.

Leafy, not stemmy, varieties of legumes and grasses are always to be preferred; likewise preferred are varieties that are resistant to insects and diseases. Resistant varieties that have been developed include aphid- and wilt- and leaf-spot-resistant alfalfas, anthracnose-resistant red clovers; rust-resistant orchardgrass; leaf spot-resistant Coastal bermudagrass. Resistant plants reduce production costs, and give larger yields and longer-lived stands. They make better quality hay because they produce more leaf and tend to drop fewer leaves.

Fertilizer and Water Management--Often Needed

Most of this country's haylands need fertilizer and many need lime to produce higher yields of better quality hay. The protein content of grasses, for example, usually can be increased by the application of nitrogen fertilizer.

In actual practice, only about 10 percent of haylands, or 12.6 million acres, are fertilized, according to the only comprehensive figures thus far reported--data from the U.S. Census of Agriculture, 1954. This census was the first to report on the quantity of commercial fertilizer used on major crops, with hay and cropland pasture combined as one of these units. On the fertilized acreage of hay and cropland pasture, the rate applied per acre averaged 12 pounds of nitrogen, 40 pounds of available phosphoric acid, 29 pounds of potash.

A grower seeking to determine what lime and fertilizer may be needed by his land for good hay crop production can get helpful information from a laboratory test of a properly taken soil sample. Soil testing laboratories are operated in every State, through the agricultural experiment stations and extension service. The plan of operation varies in different States. Information in a particular State on soil testing can be obtained from the State agricultural experiment station or county agent.

Many haylands need water management to provide proper moisture. Where good drainage does not exist naturally, drainage can be improved by such measures as grading or smoothing irregular surfaces and installing field ditches to carry off excess water. Well-drained land is highly important for alfalfa. Numerous other deep-rooted forages--legumes and grasses--thrive better on well-drained land than on wet soil.

Irrigation of forage land is widely practiced in arid areas of the West. In the East, where rainfall is more abundant, economic advantages of supplemental irrigation for hay crops are less evident, and in general are likely to be worth considering only after other measures for getting good

hay crops have been tried--that is, selecting favorable plant species and varieties, use of proper fertilization and drainage, and proper crop management. Even in the South, where many soils hold relatively little water and summer droughts are a hazard, installing a supplemental irrigation system for hay production alone may not be profitable. A shift from shallow-rooted to deeper rooted forages may give better returns. Points to recognize in considering irrigation are: the plants will require more fertilizer and may be more liable to attacks of disease-producing organisms.

Considerable research has been focused in recent years on one of the West's ranch problems: Some 4 million acres of mountain meadowland have long been relied on for hay crops and these grass meadows increasingly need renovation and improvement. The experiments undertaken to devise economic ways of improving yields and quality of the hay have recently been completed. The procedure that has given best economic returns in quantity and quality of hay yields is to combine adequate control of irrigation water and water table with applications of nitrogen fertilizer. This calls for grading the land and a shift from continuous flood irrigation, now commonly used, to intermittent watering. Reseeding graded land gives opportunity to establish the most productive, well-adapted species.

Pest Control

Insects, diseases, and other pests that prey on forages cause enormous waste in quality as well as quantity of potentially good hay crops. Chemical analysis of alfalfa hay damaged by potato leafhoppers compared with normal green alfalfa hay has shown the deterioration in quality that a pest can cause. The insect-damaged hay was stunted--because leafhoppers suck juices from alfalfa plants and cause foliage to yellow and develop poorly. This hay showed chemically a more than normal proportion of carbohydrates; less protein than normal and only half the carotene found in the normally green and leafy hay.

Worthwhile help in minimizing losses from pests can be gained by using forage varieties well adapted to the area, and varieties that have been bred for resistance to some of the troublesome forage pests.

When pest outbreaks occur, control measures are often necessary. Research is progressively developing or improving controls for economically important pests, utilizing knowledge of the habits, strength, and weakness of each pest. Crop management practices have been devised that retard many forage pests without the use of chemical pesticides. Use of effective chemicals is economical for forages in some situations. A county agent or State experiment station can provide guidance on currently recommended ways of dealing with the pests that are locally most troublesome.

Weed Control

If weeds are allowed to crowd out growing forage, the value of a hay crop may be considerably lowered in the nutrient yield per acre and palatability of the feed. Cattle tend to reject what they can of a weedy portion in hay.

Good meadow management, such as proper fertilization and grazing, tends to control some weeds. When good management practices are followed up to practical limits and broadleaved weeds persist, the relatively new selective herbicides are worth considering as supplemental knock-out weapons.

The purpose of these selective chemicals is to destroy an unwanted type of plant while leaving desirable growth unharmed or, at the most, only slightly or temporarily damaged. Success depends on the kind of herbicidal chemical and strength of the chemical and also, usually, on application at the proper time when the target weed is susceptible and the crop invaded by the weed is simultaneously tolerant to the chemical.

Research in recent years has increasingly developed these selective herbicides and procedures for specific uses.

For example, a new herbicide 4-(2,4-DB)--chemical name: 4-(2,4-dichlorophenoxy) butyric acid--kills broadleaved weeds in fields containing legumes with little if any injury to many of the legumes. The well-known 2,4-D kills these weeds without harm to associated grasses, but 2,4-D does considerable damage to alfalfa and most other forage legumes. The selective action of the new herbicide is triggered by an enzyme in the weeds, which converts the 4-(2,4-DB) into 2,4-D. Since many legumes have little or none of this enzyme, they are safeguarded.

Because correct application of these selective chemicals is important, growers are advised to consult with a county extension agent or scientists at their State Agricultural Experiment Station before applying such chemicals to forage crop plants.

Residues. In the use of all chemicals, the directions on the manufacturer's label should be followed as to the crop, amount, and time of application. These directions take into account compliance with the Federal laws on tolerances for any undesirable residues in forage.

THE BEST HAY IS CUT EARLY

Cutting hay early--when the forage approaches the peak stage of nutrient content--has been established as a timing principle giving all-around advantage.

From the standpoint of yield, even if a heavier tonnage can sometimes be harvested when haymaking is delayed until forage matures, no advantage is gained. The yield that counts, the total digestible nutrients per acre, will be smaller from a mature crop than from the same plants cut at their nutrient prime.

From the standpoint of nutrient content, during vegetative growth stages the plants accumulate stores of nutrients digestible to livestock. These are at peak at sometime in the bud or early bloom stages. Forages differ within this range in reaching peak nutrient content. If hay cutting is delayed, quality declines rapidly as the plants draw on their nutrient reserves to develop flowers and seed. There is progressive shedding of leaves. The less valuable stems become a large proportion of the matured

plant, and their usefulness as an energy and heat source in feed is lowered because the starches and sugars change chemically into less digestible fiber.

From the standpoint of feed returns, the greater nutrient content of early-cut hay proves its worth in animal feeding tests.

In one steer-feeding test it took only half as many pounds of alfalfa hay to produce 100 pounds of gain when the alfalfa was cut at bud stage as when it was cut at seed stage.

A comprehensive experiment was conducted at the Huntley Field Station, Huntley, Mont., some years ago to compare alfalfa hay cut at three growth stages for differences in yield, composition, and feed efficiency.

Yields from the early-cut hay crops ran largest, as shown by average pounds per acre harvested in three successive crop years: 8,938 when the alfalfa was cut at initial bloom; 8,888 at half bloom; 6,940 at full-bloom.

Better feed value obtained from the early-cut hay was shown in larger proportions of leafiness, protein, and total digestible nutrients in the dry matter, and also in the nutrient yields per acre.

In one test of feed efficiency, hay cut at the three stages was fed to milking cows for a year at a time as a sole ration under practical work conditions. These tests continued for two years, and clinched the evidence that the early-cut hay was the most economical feed. Figures in table 5 show that the early-cut hay averaged higher yields in milk production per cow, more milk from each 100 pounds of feed, and more milk from each acre of hay crop.

TABLE 5.--Milk Production of Dairy Cows Fed Alfalfa (as Sole Ration) Harvested at Three Stages of Growth [1]

Growth stage of alfalfa when harvested	DM[2] intake per day per cow	Average weight gain per day per cow	Average milk production		
			FCM[3] per day per cow	FCM per 100 lbs. DM	FCM per harvested acre
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Initial bloom...	34.9	0.08	27.9	79.9	6,194
Half bloom.....	34.8	.17	23.6	67.9	5,145
Full bloom.....	33.6	.0	20.8	62.0	3,814

[1] "Yield, Chemical Composition, and Feeding Value for Milk Production of Alfalfa Hay Cut at Three Stages of Maturity," J.R. Dawson, D.V. Koplan, R.R. Graves, U.S.D.A. Tech. Bull. 739. 1940.

[2] DM = dry matter.

[3] FCM = fat corrected milk (quantity of milk produced converted to a 4 percent fat basis).

Adjusting Cutting Time to Suit Forages

When advocating early cutting of hay, agricultural scientists often describe the best timing as "near" the peak of nutrient content. Some allowance needs to be made for continued productiveness of a stand. Repeated cutting of alfalfa at early bud stage, for example, would be undesirable because it would shorten the life of the stand.

Some indication of the most favorable cutting times for hay crops is given in table 6.

TABLE 6.--Favorable Growth Stage for Cutting Legumes and Grasses for Hay

Forage	Favorable growth stage for harvest
Legumes:	
Alfalfa	One-tenth bloom
Alsike clover	Early bloom
Birdsfoot trefoil	Early bloom
Crimson clover	Early bloom
Lespedeza, annual	Early bloom
Red clover	Early bloom
Sericea lespedeza	12- to 15-inch height
Sweet clovers	Early bloom
Vetches	Early bloom
Grasses:	
Bermudagrass, Coastal	16 to 18 inches high (every 4 weeks in summer)
Brome, smooth	Early bloom
Johnsongrass	When heads start to emerge
Orchardgrass	Early heading
Prairie grasses	Early heading
Timothy	Early heading or before bloom
Western wheatgrass	Early heading or before bloom

Information on cutting single forages can be applied to legume-grass mixtures by following these simple rules: If one kind of plant predominates, this kind determines the time chosen for cutting. If a mixed stand is fairly balanced, the legume is the major consideration.

If weather conditions prevent satisfactory haymaking at a recommended stage, cutting the crop for silage conserves more nutrients than waiting to make hay from mature plants.

CONSERVING QUALITY IN HAYMAKING

Once forage is cut, opportunities to increase its nutrient content are over; from then on, the haymaker's task is to conserve quality.

No one set of procedures suits all haymaking situations. Whatever methods and equipment are chosen, efficient haymaking aims at the dual goal of reducing moisture in the forage for safe storage with the least possible loss in greenness and leaves.

Moisture Reduction

The moisture content of common types of forages when fresh-cut ranges from about 65 to 80 percent. For satisfactory dry storage, this moisture is reduced to around 10 to 20 percent, depending somewhat on the form of the product. Hay baled or chopped needs to be drier for sound keeping than loose hay.

When properly dried, hay loses nutrients very gradually in storage and may remain a dependable feed for a year or longer.

Underdried hay tends to pack tight and to heat and develop mold. Overdried hay tends to shatter its leaves and to be brittle, discolored, even dusty. In either case, the associated nutrients dwindle and the palatability of the feed is poor.

Measuring moisture in farm and ranch haymaking is practical by a drying and weight loss method.

Time and the Weather

The sun is still relied on for a good start in haymaking. Fresh-cut forage in swaths dries to a loose, fluffy state so fast that the sun can accomplish this first stage of moisture removal satisfactorily in most farm and range areas. This initial drying brings moisture down to 50 percent or less, and is usually attained within 6 hours.

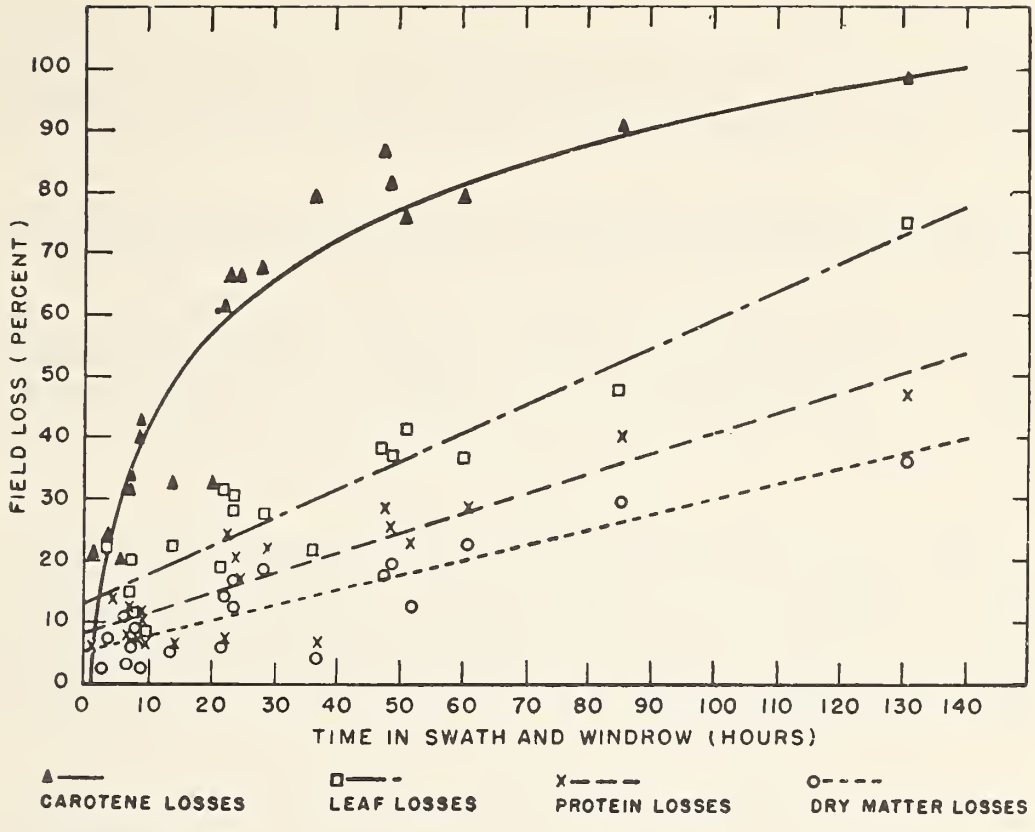
After initial drying, the reduction to the final moisture level becomes progressively slow. In areas of low rainfall, the sun can be depended on to complete the drying procedure. In other areas, the use of artifical drying equipment offers considerable advantage.

Up-to-date practices stress ways to speed hay drying in all stages, to minimize nutrient losses from time as well as risk of rain damage. Whatever the weather, a cut forage loses feed value in each additional hour of field drying. This time-loss relationship is charted in figure 1 for dry matter, protein, leaf, and carotene. The especially rapid carotene loss is due to enzyme action, which starts as soon as green forage is cut. When rain falls on partly dried forage, the losses mount because drying time is prolonged, and furthermore the rain causes leaching of soluble nutrients and leaf shattering and promotes the growth of mold.

Quality Saving Practices and Equipment

Ways of conserving green color and leaves, particularly ways that lessen the exposure of hay to time and weather during drying, are increasingly devised to suit different haymaking situations.

Since forage leaves dry faster than stems, various devices have been invented to promote uniform drying of hay lying in swaths. These conditioners include crushers and crimpers that can be attached to a tractor or mower.



BN-9311

Figure 1.--Relation between time in swath and windrow and field losses of leaves, dry matter, protein, and carotene. The forages were predominantly alfalfa.

Effects of some of these aids on the quality of field-cured hay are being experimentally studied by agricultural engineers at the Agricultural Research Center. The use of crushing and crimping equipment eliminated one night's exposure of the crop in good haymaking weather. The difference in drying rates tended to disappear after the third day indicating that this equipment would not save field-cured hay from quality loss in areas where poor drying weather and rainy days commonly recur within that time. The fluffing action of a tedder was found to give some benefit for uniform drying though tedding was not an effective alternative for crushing or crimping.

Raking swaths into windrows at the right time is a quality-saving practice. Experiments have indicated that if hay is to be field-cured, premature windrowing retards the drying rate and thereby prolongs the drying period. The fastest drying rate was achieved when windrowing was not started until the moisture content was down to 50 percent or somewhat less.

A side delivery rake in windrowing saves more leaves if fitted with more bars than the older 3- and 4-bar types. Rakes with 5 or 6 bars, now available, can lift the hay more gradually and gently and lessen leaf shattering.

The use of forced air, either heated or unheated, for final drying gives the most dependable returns in quality. These forced air systems in general consist of motor-driven fans and ducts arranged to distribute the air through the hay for uniform drying. The forced air can be applied to hay in any form; chopped, long, baled, in a hay storage, batch drier, or wagon drier.

Heating the forced air adds to drying cost, but gives additional advantages in faster drying, and the heat may be needed under humid conditions.

In a 5-year test of alfalfa preservation methods at the Agricultural Research Center, barn drying with forced air consistently saved more leaves and digestible nutrients than field drying. This was true even in ideal weather. The increase in damage when rain fell in increasing amounts--from one light shower to heavy rain--showed the risk of prolonging field exposure if hay is harvested in a region of likely frequent rain.

The barn-dried hay was usually stored the same day it was cut or the day after cutting, and total time in swaths and windrows averaged 29.4 hours. The field-cured hay, if stored without rain damage, was usually cut one day, raked the next day, and stored the second day after cutting. For field-cured hay, the total time in swaths and windrows ranged from 53.6 hours when no rain occurred to 131.3 hours when rain damage was heavy; and the average was 76.5 hours.

During this research on harvesting methods, agricultural engineers at the Research Center gathered data that indicate that it costs considerably more to harvest poor hay than good hay (table 7). This cost comparison is

TABLE 7.--Labor, Power, and Machinery Requirements for Harvesting and Storing Alfalfa, Agricultural Research Center, Beltsville, Md., 1945-47

Item	Barn-cured hay[1]	Field-cured hay	Rain-damaged field-cured hay
	Man-hours per ton of dry matter produced[2]		
Labor	4.59	4.33	6.30
Tractor	1.32	1.57	3.38
Mower	.47	.53	.65
Rake	.44	.84	2.46
Loader	.41	.44	.66
Truck	1.30	1.19	1.31
Hay hoist	.41	.30	.28
Total	8.94	9.20	15.04

[1] Fan operation, electricity, and heat required in addition.
[2] All forage was loaded onto trucks with a heavy-duty loader from the windrow.

based on losses that occur when rain interferes with putting up a prospectively good hay crop. Harvesting each ton of rain-damaged hay takes more labor and more use of machinery, especially the side delivery rake.

Dehydrators that take in green forage, either whole or chopped, and turn out dried hay within an hour or less have been on the market for several decades. Current types include stationary and portable dehydrators. This entirely artificial drying produces superior hay--provided the forage is initially good--because no leaves or green color need be lost before drying, and the drying is so rapid. The cost of installing and operating a dehydrator ordinarily limits its economic use to situations where hay is dried on a large scale or for specialty products.

AIDS AND SERVICES

Research findings that can be used to gain better returns from hay crops are progressively fitted into recommendations issued by the U. S. Department of Agriculture, the State agricultural experiment stations, State agricultural extension services, and others. Educational programs channel out information on improving hay quality through publications, demonstrations, and farmer meetings. Hay drying associations in eastern dairy areas bring farmers together to observe and discuss the newer procedures and equipment for haymaking. In addition, aids and services such as the following offer help to farmers in improving hay quality.

Certified Seed

Certified seed of newer, improved varieties of grasses and legumes are increasingly available to farmers. These seed are produced, processed, tagged, and sealed under the supervision of State certifying agencies. The label states that the seed when sealed were officially approved as having been produced, harvested, and processed under conditions for protecting their genetic purity and characteristics of the variety. The National Foundation Seed Project, established in 1949, assumed the task of speeding up quantity production of certified seed of improved legume and grass varieties having wide regional adaptation. The project is operated cooperatively by the U. S. Department of Agriculture, State agencies, seed growers, and seed distributors. It supervises the production and distribution of foundation seed from which commercial crops of certified seed are grown, and in 10 years it has made spectacular progress toward its program goal: providing farmers with certified seed of superior forage varieties in the volume they need.

Tests were made a few years ago of 21 lots of certified seed and 163 lots not certified of the same improved alfalfa variety. Indiana and Minnesota cooperated with ARS scientists on these tests, and Ranger was the tested variety. Ninety percent of the certified Ranger alfalfa seed lots passed standard tests for measuring wilt-resistance and winter hardiness. Only 45 percent of the non-certified Ranger seed lots passed the same tests.

Forage Testing

In a few States, dairymen and livestock growers can now get hay and silages laboratory tested for guidance in improving their forage and feed

economy. This relatively new type of State service is somewhat similar to the well-known soil testing program, already mentioned (page 5). One forage-test plan, recently launched, is described to give some idea of the scope and value of such projects:

Pennsylvania farmers can get the feed value of their hay and silage crops tested at a Forage Testing Service set up at the Pennsylvania State University. The service is on a fee basis. An applicant is given directions for taking forage samples and information forms to fill out and return with his samples. The farmer and the county extension office concerned receive duplicate reports. The report on each sample shows the crude protein, estimated digestible protein, crude fiber, and estimated total digestible nutrients on both a dry matter and "as fed" basis. The report shows also the moisture content and quality grade of the sample.

At no extra charge, an applicant can receive a suggested feeding program, including least-cost feed formulas for beef or dairy cattle, sheep, or swine. This information is sent only if specifically requested and when the applicant has tests of all roughages he is using and fills out special forms. Farm studies indicate that having 6 to 10 samples a year tested at a cost of $30 to $50 may save a dairy farmer with a 25-cow herd $700 or more in feed costs, increased milk production, or both combined.

Insect Situation Warnings

Important to hay crop growers is the official service operated by Federal and State entomologists to alert farmers and ranchers when harmful insects are multiplying alarmingly or invading new areas. Survey teams systematically gather information on the insect situation in their States. Federal entomologists consolidate State reports weekly into "The Cooperative Economic Insect Report." Watching out for these warnings enables growers to take prompt action when it is needed. The warning reports and recommendations for action are channeled by county extension agents, newspapers, radio, and television.

Weather Forecasts

Keeping in touch with weather news is valuable aid for getting haymaking off to a favorable start--or considering the alternative of silagemaking to avoid rain-damaged hay. The accuracy of the 24-hour forecasts of the U. S. Weather Bureau averages 85 to 90 percent, varying in different parts of the country. Special bulletins and warnings are issued to supplement a daily forecast.

General forecasts issued two or more days ahead indicate probabilities based on the expected advances of distant air masses and other upper air conditions that are highly complex in their interaction. Since an inflowing air mass--and rain clouds--may shift direction and change in speed, these preliminary advices are subject to revision as a forecast interval narrows.

Three-day agricultural weather forecasts are issued each morning by the U. S. Weather Bureau and are rather widely publicized on early morning radio and television farm programs.

There is some prospect of a closer tailoring of local weather services to leading crops. In one pilot study, a U. S. Weather Bureau meteorologist has been assigned to work with USDA and State agricultural research scientists at the Delta Branch Experiment Station, Stoneville, Miss., on developing techniques for issuing types of farm operational forecasts geared to Delta crops, notably cotton. The pilot program calls for some research and for issuing twice-a-day farm operational forecasts as well as daily, 5-day, and 30-day forecasts through crop season. Such techniques applied to haymaking would be widely useful, if the experimental service can eventually be extended.

Federal Grading

Federal or Federal-State hay inspection is a service available on a fee basis in some areas--but not nationwide. Inspectors are located at shipping points or terminal markets. The fee is based on the tonnage graded, with a minimum fee for small lots. Detailed information on U. S. hay grades may be had from the Grain Division, Agricultural Marketing Service, U. S. Department of Agriculture, Washington 25, D. C.

LOOKING AHEAD

Scientists in all lines of hay research can see many further possibilities for helping farmers to produce high-quality hay and get more dependable, economical feed from hay crops. Here are some possible haymaking aids-of-the-future:

* Pre-drying treatments, such as blanching, to save more of the nutrients and dry matter tonnage in a hay crop.

* Anti-oxidants that halt enzyme action, to stablize the carotene in cut forage and save more of this high-value nutrient.

* Improved forage-harvesting machines adapted to farms where small to medium tonnages of hay are stored.

* Improved and more economical field equipment for making hay wafers or pellets. These compressed products, now made with expensive machinery are space-saving and convenient, and tests indicate that cattle eat heartily of hay in these forms.